

CLAIMS

What is claimed is:

1 1. A thermal management system for an integrated circuit die, comprising:
2 a temperature detection element formed directly on said integrated circuit die, said
3 temperature detection element including at least one temperature sensor having an
4 output;
5 a power modulation element formed directly on said integrated circuit die and configured
6 to reduce power consumption of said integrated circuit die in response to a logical
7 change in state at said output of said at least one temperature sensor;
8 a control element formed directly on said integrated circuit die, said control element
9 including at least one register providing an enable/disable bit for said thermal
10 management system; and
11 a visibility element formed directly on said integrated circuit die and configured to
12 indicate a status of said output of said at least one temperature sensor.

1 2. The system of claim 1, said at least one temperature sensor comprising:
2 a reference voltage source providing a reference voltage;
3 a programmable voltage source providing a programmable voltage proportional to a
4 temperature of said integrated circuit die; and
5 a comparator having one input coupled via a first signal line to said reference voltage
6 source and another input coupled via a second signal line to said programmable
7 voltage source, said comparator configured to provide said logical change in state
8 at said output of said at least one temperature sensor in response to said
9 programmable voltage substantially equaling said reference voltage.

1 3. The system of claim 2, further comprising a pulse dampener coupled to
2 said first signal line and configured to at least partially remove electrical noise from said
3 reference voltage.

1 4. The system of claim 2, further comprising an analog filter coupled to said
2 second signal line and said first signal line, said analog filter configured to detect voltage
3 spikes present in said reference voltage and to add substantially identical voltage spikes
4 to said programmable voltage.

1 5. The system of claim 2, further comprising a digital filter coupled to an
2 output of said comparator, said digital filter including an up-down counter configured to
3 count clock pulses, said up-down counter configured to increment once for each clock
4 pulse detected when said comparator output is at a logical high and to decrement once for
5 each clock pulse detected when said comparator output is at a logical low.

1 6. The system of claim 1, said control element further including another
2 register selected from a group consisting of a register configured to selectively disengage
3 a specified portion of said thermal management system, a register configured to enable
4 said thermal management system in response to an occurrence of an external event, a
5 register configured to force said thermal management system active while overriding a
6 disable bit provided by said at least one register, and a register configured to allow
7 external software and hardware to enable said thermal management system.

1 7. The system of claim 1, said visibility element including at least one device
2 selected from a group consisting of a register configured to indicate said status of said
3 temperature sensor output, a register providing a sticky bit, a counter configured to count
4 a number of lost clock cycles resulting from operation of said thermal management
5 system, and circuitry configured to generate an interrupt when said temperature sensor
6 output transitions to a different logical state.

1 8. The system of claim 1, said power modulation element configured to
2 lower a supply voltage to said integrated circuit die, lower a frequency of a clock signal
3 provided by internal clock circuitry on said integrated circuit die, perform clock gating of
4 said clock signal provided by said internal clock circuitry, perform clock throttling of said
5 clock signal provided by said internal clock circuitry, selectively block clock pulses of
6 said clock signal provided by said internal clock circuitry, disable at least one of a
7 plurality of functional units on said integrated circuit die, limit instructions sent to at least
8 one of said plurality of functional units on said integrated circuit die, or change a
9 behavior of at least one of said plurality of functional units on said integrated circuit die.

1 9. A microprocessor, comprising:
2 a die having a plurality of functional units formed thereon;
3 internal clock circuitry formed on said die and coupled to at least one of said plurality of
4 functional units; and
5 a thermal management system formed directly on said die, comprising:
6 a temperature detection element including at least one temperature sensor having
7 an output;
8 a power modulation element configured to reduce power consumption of at least
9 one of said functional units in response to a logical change in state at said
10 output of said at least one temperature sensor;
11 a control element including at least one register providing an enable/disable bit for
12 said thermal management system; and
13 a visibility element configured to indicate a status of said output of said at least
14 one temperature sensor.

1 10. The microprocessor of claim 9, said at least one temperature sensor
2 comprising:
3 a reference voltage source providing a reference voltage;
4 a programmable voltage source providing a programmable voltage proportional to a
5 temperature of said die; and
6 a comparator having one input coupled via a first signal line to said reference voltage
7 source and another input coupled via a second signal line to said programmable
8 voltage source, said comparator configured to provide said logical change in state
9 at said output of said at least one temperature sensor in response to said
10 programmable voltage substantially equaling said reference voltage.

1 11. The microprocessor of claim 10, further comprising a pulse dampener
2 coupled to said first signal line and configured to at least partially remove electrical noise
3 from said reference voltage.

1 12. The microprocessor of claim 10, further comprising an analog filter
2 coupled to said second signal line and said first signal line, said analog filter configured
3 to detect voltage spikes present in said reference voltage and to add substantially identical
4 voltage spikes to said programmable voltage.

1 13. The microprocessor of claim 10, further comprising a digital filter coupled
2 to an output of said comparator, said digital filter including an up-down counter
3 configured to count clock pulses, said up-down counter configured to increment once for
4 each clock pulse detected when said comparator output is at a logical high and to
5 decrement once for each clock pulse detected when said comparator output is at a logical
6 low.

1 14. The microprocessor of claim 9, said control element further including
2 another register selected from a group consisting of a register configured to selectively
3 disengage a specified portion of said thermal management system, a register configured
4 to enable said thermal management system in response to an occurrence of an external
5 event, a register configured to force said thermal management system active while
6 overriding a disable bit provided by said at least one register, and a register configured to
7 allow external software and hardware to enable said thermal management system.

1 15. The microprocessor of claim 9, said visibility element including at least
2 one device selected from a group consisting of a register configured to indicate said status
3 of said temperature sensor output, a register providing a sticky bit, a counter configured
4 to count a number of lost clock cycles resulting from operation of said thermal
5 management system, and circuitry configured to generate an interrupt when said
6 temperature sensor output transitions to a different logical state.

1 16. The microprocessor of claim 9, said power modulation element configured
2 to lower a supply voltage to said die, lower a frequency of a clock signal provided by said
3 internal clock circuitry, perform clock gating of said clock signal provided by said
4 internal clock circuitry, perform clock throttling of said clock signal provided by said
5 internal clock circuitry, selectively block clock pulses of said clock signal provided by
6 said internal clock circuitry, disable at least one of said plurality of functional units on
7 said die, limit instructions sent to at least one of said plurality of functional units on said
8 die, or change a behavior of at least one of said plurality of functional units on said die.

1 17. A computer system, comprising:
2 at least one memory device coupled to a bus;
3 at least one microprocessor coupled to said bus and said at least one memory device, said
4 at least one microprocessor comprising:
5 a die having a plurality of functional units formed thereon;
6 internal clock circuitry formed on said die and coupled to at least one of said
7 plurality of functional units;
8 a temperature detection element formed directly on said die, said temperature
9 detection element including at least one temperature sensor having an
10 output;
11 a power modulation element formed directly on said die and configured to reduce
12 power consumption of at least one of said functional units in response to a
13 logical change in state at said output of said at least one temperature
14 sensor;
15 a control element formed directly on said die, said control element including at
16 least one register providing an enable/disable bit for said thermal
17 management system; and
18 a visibility element formed directly on said die and configured to indicate a status
19 of said output of said at least one temperature sensor, said temperature
20 detection, power modulation, control, and visibility elements comprising a
21 thermal management system for said die.

1 18. The computer system of claim 17, said at least one temperature sensor
2 comprising:
3 a reference voltage source providing a reference voltage;
4 a programmable voltage source providing a programmable voltage proportional to a
5 temperature of said die; and
6 a comparator having one input coupled via a first signal line to said reference voltage
7 source and another input coupled via a second signal line to said programmable
8 voltage source, said comparator configured to provide said logical change in state
9 at said output of said at least one temperature sensor in response to said
10 programmable voltage substantially equaling said reference voltage.

1 19. The computer system of claim 18, further comprising a pulse dampener
2 coupled to said first signal line and configured to at least partially remove electrical noise
3 from said reference voltage.

1 20. The computer system of claim 18, further comprising an analog filter
2 coupled to said second signal line and said first signal line, said analog filter configured
3 to detect voltage spikes present in said reference voltage and to add substantially identical
4 voltage spikes to said programmable voltage.

1 21. The computer system of claim 18, further comprising a digital filter
2 coupled to an output of said comparator, said digital filter including an up-down counter
3 configured to count clock pulses, said up-down counter configured to increment once for
4 each clock pulse detected when said comparator output is at a logical high and to
5 decrement once for each clock pulse detected when said comparator output is at a logical
6 low.

1 22. The computer system of claim 17, said control element further including
2 another register selected from a group consisting of a register configured to selectively
3 disengage a specified portion of said thermal management system, a register configured
4 to enable said thermal management system in response to an occurrence of an external
5 event, a register configured to force said thermal management system active while
6 overriding a disable bit provided by said at least one register, and a register configured to
7 allow external software and hardware to enable said thermal management system.

1 23. The computer system of claim 17, said visibility element including at least
2 one device selected from a group consisting of a register configured to indicate said status
3 of said temperature sensor output, a register providing a sticky bit, a counter configured
4 to count a number of lost clock cycles resulting from operation of said thermal
5 management system, and circuitry configured to generate an interrupt when said
6 temperature sensor output transitions to a different logical state.

1 24. The computer system of claim 17, said power modulation element
2 configured to lower a supply voltage to said die, lower a frequency of a clock signal
3 provided by said internal clock circuitry, perform clock gating of said clock signal
4 provided by said internal clock circuitry, perform clock throttling of said clock signal
5 provided by said internal clock circuitry, selectively block clock pulses of said clock
6 signal provided by said internal clock circuitry, disable at least one of said plurality of
7 functional units on said die, limit instructions sent to at least one of said plurality of
8 functional units on said die, or change a behavior of at least one of said plurality of
9 functional units on said die.

1 25. A method of performing thermal management on a microprocessor,
2 comprising:
3 providing an enable bit to a register of a thermal management system to activate said
4 thermal management system;
5 measuring a temperature on a die of said microprocessor with a sensor of said thermal
6 management system;
7 providing a logical low at an output of said sensor when said temperature is below a trip
8 point;
9 providing a logical high at said sensor output when said temperature equals or exceeds
10 said trip point;
11 engaging a power reduction mechanism to reduce power consumption of said die in
12 response to said logical high at said sensor output; and
13 providing an indication of a logical status of said output of said sensor to an external
14 device.

1 26. The method of claim 25, said engaging a power reduction mechanism
2 comprising an act selected from a group consisting of lowering a supply voltage to said
3 die, lowering a frequency of a clock signal provided by internal clock circuitry of said
4 microprocessor, performing clock gating of said clock signal provided by said internal
5 clock circuitry, performing clock throttling of said clock signal provided by said internal
6 clock circuitry, selectively blocking clock pulses of said clock signal provided by said
7 internal clock circuitry, disabling at least one of a plurality of functional units on said
8 microprocessor, limiting instructions sent to at least one of said plurality of functional
9 units on said microprocessor, and changing a behavior of at least one of said plurality of
10 functional units on said microprocessor.

1 27. The method of claim 25, said providing an enable bit to a register of said
2 thermal management system comprising providing an enable bit to said register from an
3 external operating system.

1 28. The method of claim 25, further comprising:
2 engaging said power reduction mechanism for a specified time period;
3 polling said sensor output after expiration of said specified time period;
4 engaging said power reduction mechanism for at least another said specified time period
5 when said sensor output exhibits said logical high; and
6 halting said power reduction mechanism when said sensor output exhibits said logical
7 low;

1 29. The method of claim 25, further comprising:
2 engaging said power reduction mechanism for a specified time period;
3 continuously polling said sensor output after expiration of said specified time period; and
4 halting said power reduction mechanism when said sensor output exhibits said logical
5 low.

1 30. The method of claim 25, further comprising:
2 providing said logical low at said sensor output when said temperature is below an untrip
3 point, said untrip point less than said trip point; and
4 halting said power reduction mechanism in response to said logical low.

1 31. The method of claim 25, further comprising:
2 coupling an up-down counter to said sensor output;
3 incrementing said up-down counter once for every clock pulse of said clock signal
4 provided by said internal clock circuitry when said sensor output exhibits said
5 logical high; and
6 decrementing said up-down counter once for every clock pulse of said clock signal
7 provided by said internal clock circuitry when said sensor output exhibits said
8 logical low.

1 32. The method of claim 25, further comprising:
2 defining a plurality of trip temperatures, a highest of said plurality of trip temperatures
3 corresponding to said trip point;
4 assigning a plurality of duty cycle values to said plurality of trip temperatures, one duty
5 cycle value of said plurality of duty cycle values corresponding to at least one of
6 said plurality of trip temperatures; and
7 providing a clock signal from said internal clock circuitry exhibiting said one duty cycle
8 value in response to said temperature substantially equaling said at least one
9 corresponding trip temperature.

1 33. The method of claim 25, further comprising counting a number of clock
2 cycles eliminated from an output of said internal clock circuitry resulting from said
3 engaging a power reduction mechanism.

1 34. An apparatus, comprising:
2 a temperature detection element, said temperature detection element including at least
3 one temperature sensor having an output;
4 a power modulation element, said power modulation element to reduce power
5 consumption of an integrated circuit die in response to a logical change in state at
6 said output of said at least one temperature sensor;
7 a visibility element, said visibility element to indicate a status of said output of said at
8 least one temperature sensor, said visibility element comprising:
9 a register to indicate said status of said temperature sensor output;
10 a register providing a sticky bit;
11 a counter to count a number of lost clock cycles resulting from operation of said
12 apparatus; and
13 circuitry to generate an interrupt when said temperature sensor output transitions
14 to a different logical state.

1 35. The apparatus of claim 34, further including a control element, said
2 control element comprising:
3 a register providing an enable/disable bit for said apparatus;
4 a register configured to selectively disengage a specified portion of said apparatus;
5 a register configured to enable said apparatus in response to an occurrence of an external
6 event;
7 a register configured to force said apparatus active while overriding a disable bit provided
8 at said enable/disable bit; and
9 a register configured to allow external software and hardware to enable said apparatus.

1 36. The system of claim 34, said power modulation element configured to
2 lower a supply voltage to said integrated circuit die, lower a frequency of a clock signal
3 provided by internal clock circuitry on said integrated circuit die, perform clock gating of
4 said clock signal provided by said internal clock circuitry, perform clock throttling of said
5 clock signal provided by said internal clock circuitry, selectively block clock pulses of
6 said clock signal provided by said internal clock circuitry, disable at least one of a
7 plurality of functional units on said integrated circuit die, limit instructions sent to at least
8 one of said plurality of functional units on said integrated circuit die, or change a
9 behavior of at least one of said plurality of functional units on said integrated circuit die.